

# FAN2103 — TinyBuck™

## 3A, 24V Input, Integrated Synchronous Buck Regulator

### Features

- 3A Output Current
- Over 95% Efficiency
- Fully Synchronous Operation with Integrated Schottky Diode on Low-side MOSFET Boosts Efficiency
- Programmable Frequency Operation (200KHz to 600KHz)
- Power-good Signal
- Accepts Ceramic Capacitors on Output
- External Compensation for Flexible Design
- Wide Input Range: 3V to 24V
- Output Voltage Range: 0.8V to 90%V<sub>IN</sub>
- Input Under-voltage Lockout
- Programmable Over-current Limit
- Under-voltage, Over-voltage, and Thermal Protections
- 5x6mm, 25-pin, 3-pad MLP

### Applications

- Graphics Cards
- Battery-powered Equipment
- Set-top Boxes
- Point-of-load Regulation
- Servers

### Description

The FAN2103 TinyBuck™ is an easy-to-use, cost- and space-efficient, 3A synchronous buck solution. It enables designers to solve high current requirements in a small area with minimal external components.

External compensation, programmable switching frequency, and current limit features allow for design optimization and flexibility.

The summing current mode modulator uses lossless current sensing for current feedback and over-current, and includes voltage feedforward.


Fairchild's advanced BiCMOS power process, combined with low R<sub>DS(ON)</sub> internal MOSFETs and a thermally efficient MLP package provide the ability to dissipate high power in a small package.

Output over-voltage, under-voltage, and thermal shutdown protections plus power-good, help protect the devices from damage during fault conditions.

### Related Application Notes

- [AN-5067 – PCB Land Pattern Design and Surface Mount Guidelines for MLP Packages](#)

### Ordering Information

Part Number	Operating Temperature Range	Package	 Eco Status	Packing Method
FAN2103MPX	-10°C to 85°C	25-Pin Molded Leadless Package (MLP) 5x6mm	Green	Tape and Reel
FAN2103EMPX	-40°C to 85°C	25-Pin Molded Leadless Package (MLP) 5x6mm	Green	Tape and Reel

 For Fairchild's definition of "green" please visit: [http://www.fairchildsemi.com/company/green/rohs\\_green.html](http://www.fairchildsemi.com/company/green/rohs_green.html).



## Pin Configuration

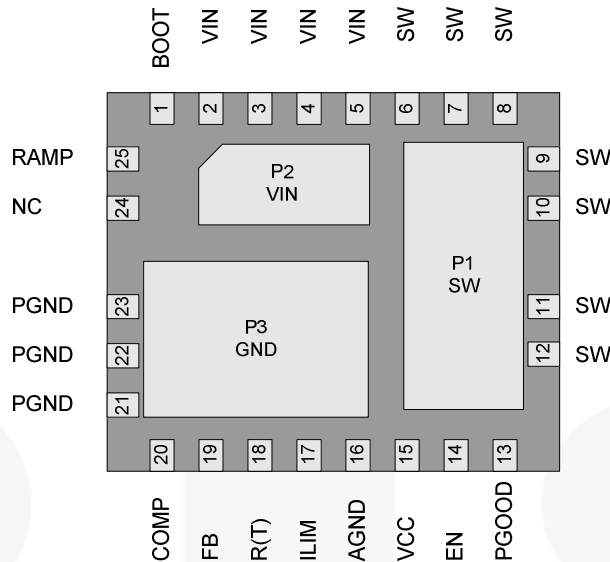


Figure 3. MLP 5x6mm Pin Configuration (Bottom View)

## Pin Definitions

Pin	Name	Description
P1, 6-12	SW	<b>Switching Node.</b>
P2, 2-5	VIN	<b>Power Input Voltage.</b> Connect to the main input power source.
P3, 21-23	PGND	<b>Power Ground.</b> Power return and Q2 source.
1	BOOT	<b>High-side Drive BOOT Voltage.</b> Connect through capacitor ( $C_{BOOT}$ ) to SW. The IC includes an internal synchronous bootstrap diode to recharge the capacitor on this pin to $V_{CC}$ when SW is LOW.
13	PGOOD	<b>Power-Good Flag.</b> An open-drain output that pulls LOW when FB is outside a $\pm 10\%$ range of the reference when EN is HIGH. PGOOD does not assert HIGH until the fault latch is enabled.
14	EN	<b>ENABLE.</b> Enables operation when pulled to logic HIGH or left open. Toggling EN resets the regulator after a latched fault condition. This input has an internal pull-up when the IC is functioning normally. When a latched fault occurs, EN is discharged by a current sink.
15	VCC	<b>Input Bias Supply for IC.</b> The IC's logic and analog circuitry are powered from this pin.
16	AGND	<b>Analog Ground.</b> The signal ground for the IC. All internal control voltages are referred to this pin. Tie this pin to the ground island/plane through the lowest impedance connection.
17	ILIM	<b>Current Limit.</b> A resistor ( $R_{ILIM}$ ) from this pin to AGND can be used to program the current-limit trip threshold lower than the default setting.
18	R(T)	<b>Oscillator Frequency.</b> A resistor ( $R_T$ ) from this pin to AGND sets the PWM switching frequency.
19	FB	<b>Output Voltage Feedback.</b> Connect through a resistor divider to the output voltage.
20	COMP	<b>Compensation.</b> Error amplifier output. Connect the external compensation network between this pin and FB.
24	NC	<b>No Connect.</b> This pin is not used.
25	RAMP	<b>Ramp Amplitude.</b> A resistor ( $R_{RAMP}$ ) connected from this pin to VIN sets the ramp amplitude and provides voltage feedforward functionality.

## Absolute Maximum Ratings

Stresses exceeding the absolute maximum ratings may damage the device. The device may not function or be operable above the recommended operating conditions and stressing the parts to these levels is not recommended. In addition, extended exposure to stresses above the recommended operating conditions may affect device reliability. The absolute maximum ratings are stress ratings only.

Parameter	Conditions	Min.	Max.	Unit
VIN to PGND			28	V
VCC to AGND	AGND = PGND		6	V
BOOT to PGND			35	V
BOOT to SW		-0.3	6.0	V
SW to PGND	Transient (t < 20ns, f < 600KHz)	-5	30	V
All other pins		-0.3	V <sub>CC</sub> +0.3	V
ESD	Human Body Model, JESD22-A114	2		kV
	Charged Device Model, JESD22-C101	2		

## Recommended Operating Conditions

The Recommended Operating Conditions table defines the conditions for actual device operation. Recommended operating conditions are specified to ensure optimal performance to the datasheet specifications. Fairchild does not recommend exceeding them or designing to absolute maximum ratings.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
V <sub>CC</sub>	Bias Voltage	VCC to AGND	4.5	5.0	5.5	V
V <sub>IN</sub>	Supply Voltage	VIN to PGND	3		24	V
T <sub>A</sub>	Ambient Temperature	FAN2103M	-10		+85	°C
		FAN2103EM	-40		+85	°C
T <sub>J</sub>	Junction Temperature				+125	°C

## Thermal Information

Symbol	Parameter		Min.	Typ.	Max.	Unit
T <sub>STG</sub>	Storage Temperature		-65		+150	°C
T <sub>L</sub>	Lead Soldering Temperature, 10 Seconds				+300	°C
T <sub>VP</sub>	Vapor Phase, 60 Seconds				+215	°C
T <sub>I</sub>	Infrared, 15 Seconds				+220	°C
θ <sub>JC</sub>	Thermal Resistance: Junction-to-Case	P1 (Q2)		4		°C/W
		P2 (Q1)		7		°C/W
		P3		4		°C/W
θ <sub>J-PCB</sub>	Thermal Resistance: Junction-to-Mounting Surface			35 <sup>(1)</sup>		°C/W
P <sub>D</sub>	Power Dissipation, T <sub>A</sub> = 25°C				2.8 <sup>(1)</sup>	W

### Note:

- Typical thermal resistance when mounted on a four-layer, two-ounce PCB, as shown in Figure 25. Actual results are dependent on mounting method and surface related to the design.

## Electrical Specifications

Recommended operating conditions are the result of using the circuit shown in Figure 1 unless otherwise noted.

Parameter	Conditions	Min.	Typ.	Max.	Unit
<b>Power Supplies</b>					
V <sub>CC</sub> Current	SW = Open, FB = 0.7V, V <sub>CC</sub> = 5V, f <sub>SW</sub> = 600KHz		8	12	mA
	Shutdown: EN = 0, V <sub>CC</sub> = 5V		7	10	μA
V <sub>CC</sub> UVLO Threshold	Rising V <sub>CC</sub>	4.1	4.3	4.5	V
	Hysteresis		300		mV
<b>Oscillator</b>					
Frequency	R <sub>T</sub> = 50KΩ	255	300	345	KHz
	R <sub>T</sub> = 24KΩ	540	600	660	KHz
Minimum On-Time <sup>(2)</sup>			50	65	ns
Ramp Amplitude, pk-pk	16V <sub>IN</sub> , 1.8V <sub>OUT</sub> , R <sub>T</sub> = 30KΩ, R <sub>RAMP</sub> = 200KΩ		0.53		V
Minimum Off-Time <sup>(2)</sup>			100	150	ns
<b>Reference</b>					
Reference Voltage (V <sub>FB</sub> )	FAN2103M, 25°C	794	800	806	mV
	FAN2103EM, 25°C	795	800	805	mV
Temperature Coefficient	FAN2103M, -10 to +85°C		50		PPM
	FAN2103EM, -40 to +85°C		70		PPM
<b>Error Amplifier</b>					
DC Gain <sup>(2)</sup>	V <sub>CC</sub> = 5V	80	85		dB
Gain Bandwidth Product <sup>(2)</sup>		12	15		MHz
Output Voltage (V <sub>COMP</sub> )		0.4		3.2	V
Output Current, Sourcing	V <sub>CC</sub> = 5V, V <sub>COMP</sub> = 2.2V	1.5	2.2		mA
Output Current, Sinking	V <sub>CC</sub> = 5V, V <sub>COMP</sub> = 1.2V	0.8	1.2		mA
FB Bias Current	V <sub>FB</sub> = 0.8V, 25°C	-850	-650	-450	nA
<b>Protection and Shutdown</b>					
Current Limit	R <sub>LIM</sub> open	3.8	5.0	7.0	A
I <sub>LIM</sub> Current	25°C, V <sub>CC</sub> = 5V	9	10	11	μA
Over-Temperature Shutdown	Internal IC Temperature		+160		°C
Over-Temperature Hysteresis			+30		°C
Over-Voltage Threshold	2 Consecutive Clock Cycles	110	115	120	%V <sub>OUT</sub>
Under-Voltage Shutdown	16 Consecutive Clock Cycles	68	73	78	%V <sub>OUT</sub>
Fault Discharge Threshold	Measured at FB Pin		250		mV
Fault Discharge Hysteresis	Measured at FB Pin (V <sub>FB</sub> ~500mV)		250		mV
<b>Soft-Start</b>					
V <sub>OUT</sub> to Regulation (T0.8)	Frequency = 600KHz		5.3		ms
Fault Enable/SSOK (T1.0)			6.7		ms

### Note:

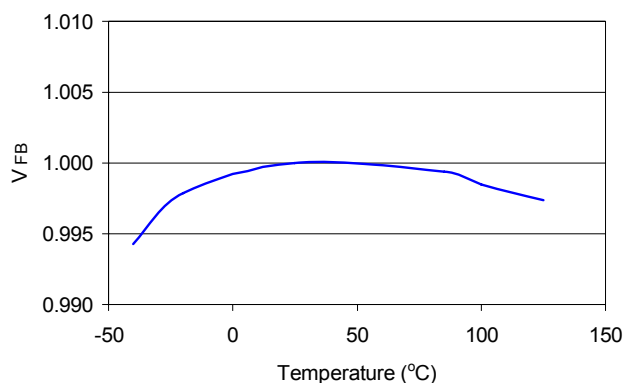
- Specifications guaranteed by design and characterization; not production tested.

**Electrical Specifications** (Continued)

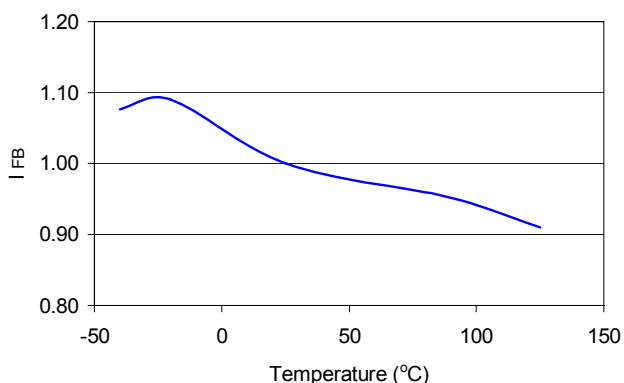
Recommended operating conditions are the result of using the circuit shown in Figure 1 unless otherwise noted.

Parameter	Conditions	Min.	Typ.	Max.	Unit
<b>Control Functions</b>					
EN Threshold, Rising			1.35	2.00	V
EN Hysteresis			250		mV
EN Pull-up Resistance			800		K $\Omega$
EN Discharge Current	Auto-restart Mode		1		$\mu$ A
FB OK Drive Resistance				800	$\Omega$
PGOOD Threshold (Compared to $V_{REF}$ )	$FB < V_{REF}$	-14	-11	-8	% $V_{REF}$
	$FB > V_{REF}$	+7	+10	+13	% $V_{REF}$
PGOOD Output Low	$I_{OUT} \leq 2mA$			0.4	V

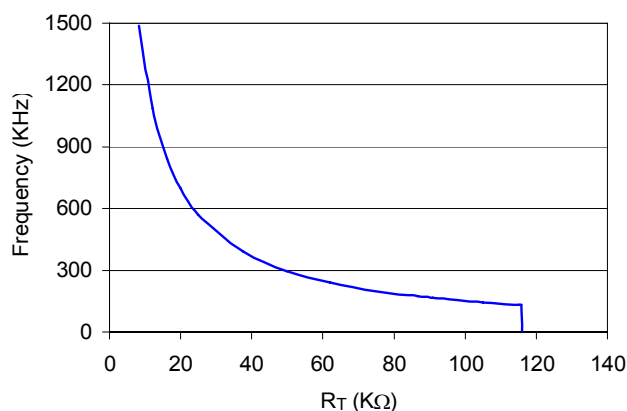
## Typical Characteristics



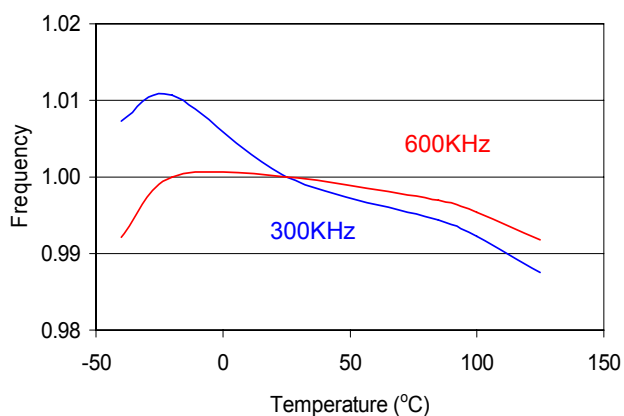
**Figure 4. Reference Voltage ( $V_{FB}$ ) vs. Temperature, Normalized**



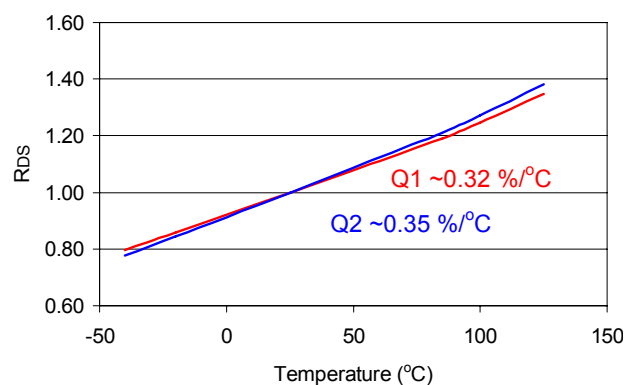
**Figure 5. Reference Bias Current ( $I_{FB}$ ) vs. Temperature, Normalized**



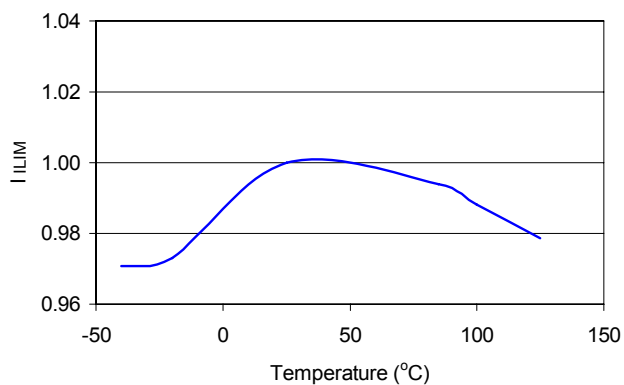
**Figure 6. Frequency vs.  $R_T$**



**Figure 7. Frequency vs. Temperature, Normalized**



**Figure 8.  $R_{DS}$  vs. Temperature, Normalized ( $V_{CC} = V_{GS} = 5V$ )**



**Figure 9.  $I_{LIM}$  Current ( $I_{LIM}$ ) vs. Temperature, Normalized**

## Application Circuit

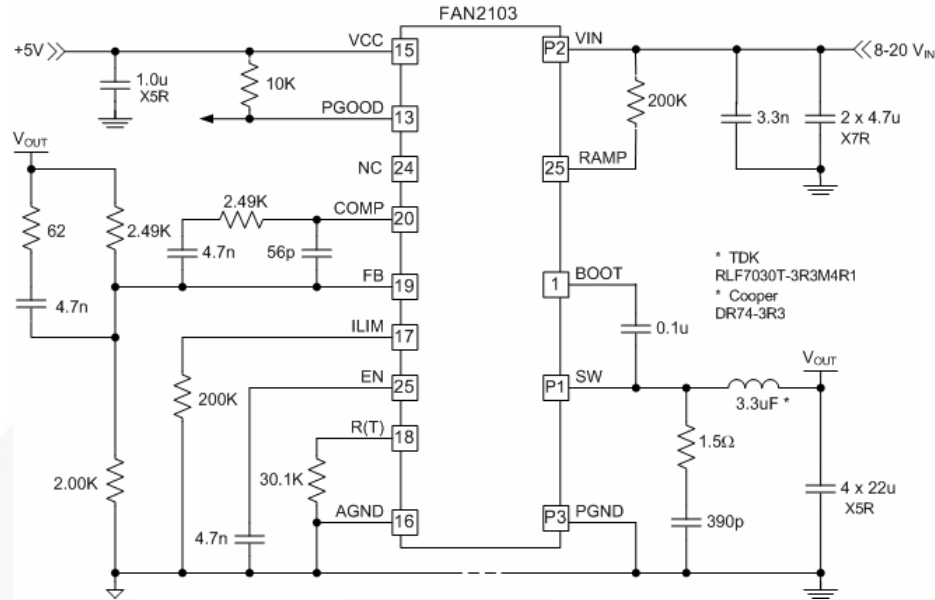


Figure 10. Application Circuit: 1.8 V<sub>OUT</sub>, 500KHz

## Typical Performance Characteristics

Typical operating characteristics using the circuit shown in Figure 10. V<sub>IN</sub>=16V, V<sub>CC</sub>=5V, unless otherwise specified.

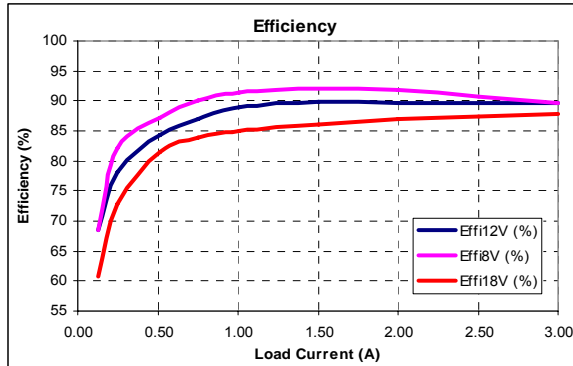


Figure 11. 1.8 V<sub>OUT</sub> Efficiency Over V<sub>IN</sub> vs. Load

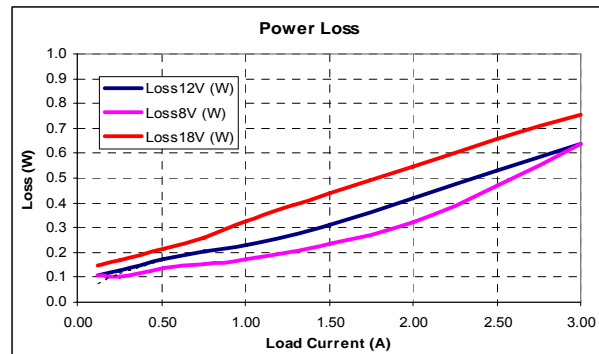


Figure 12. 1.8 V<sub>OUT</sub> Dissipation Over V<sub>IN</sub> vs. Load

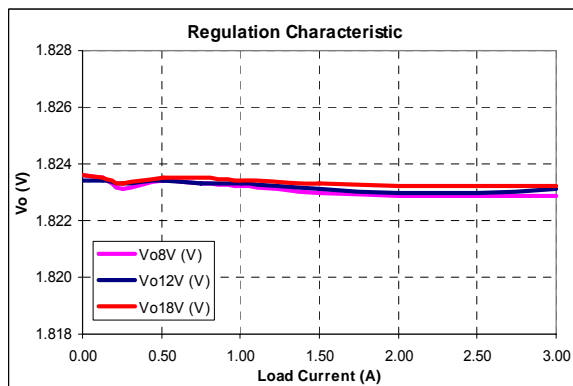


Figure 13. 1.8 V<sub>OUT</sub> Regulation vs. Load

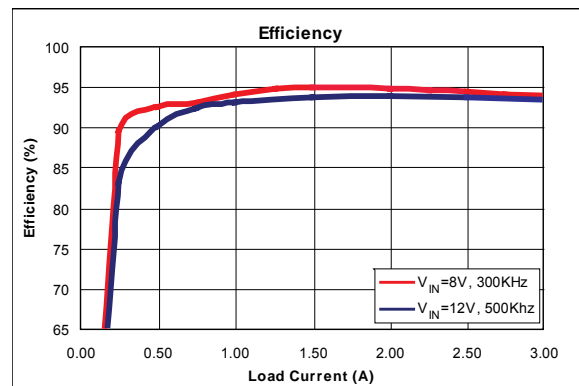


Figure 14. 3.3 V<sub>OUT</sub> Efficiency vs. Load  
(Circuit Values Changed)



## Typical Performance Characteristics (Continued)

Typical operating characteristics using the circuit shown in Figure 10.  $V_{IN}=12V$ ,  $V_{CC}=5V$ , unless otherwise specified.

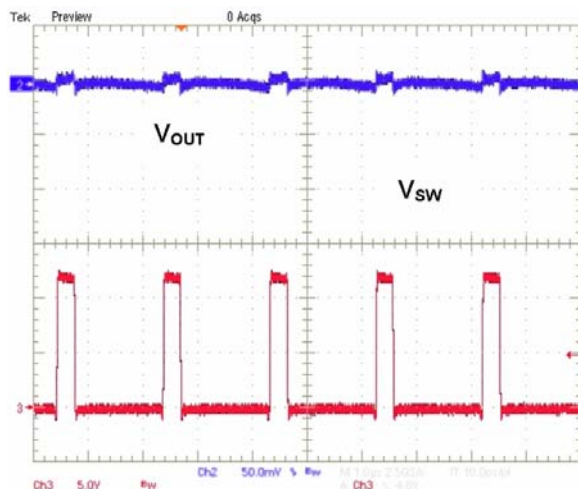


Figure 15. SW and  $V_{OUT}$  Ripple, 3A Load

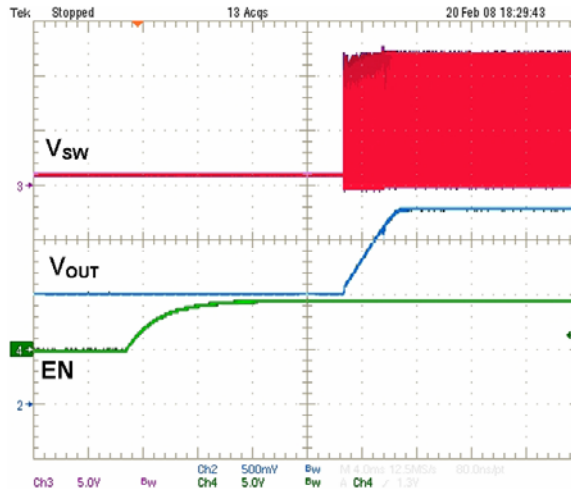


Figure 16. Start up with 1V Pre-Bias on  $V_{OUT}$

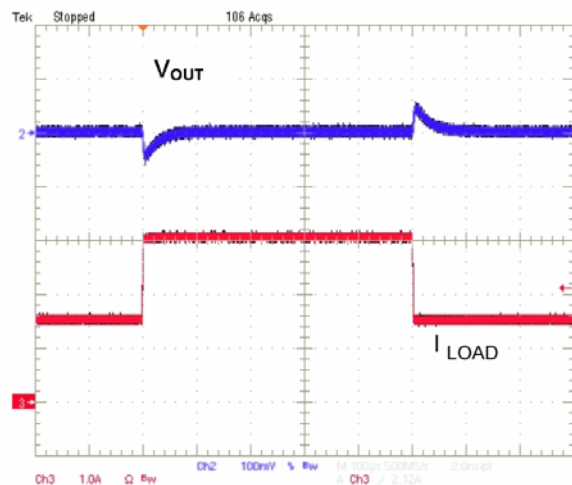


Figure 17. Transient Response, 1.5-3A Load  
(Circuit Values Changed)

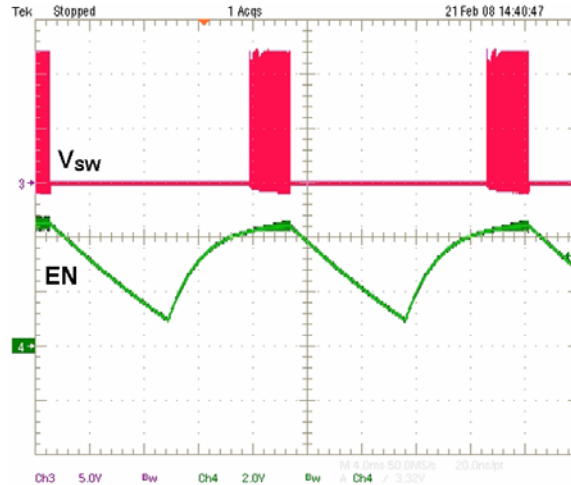


Figure 18. Re-start on Fault

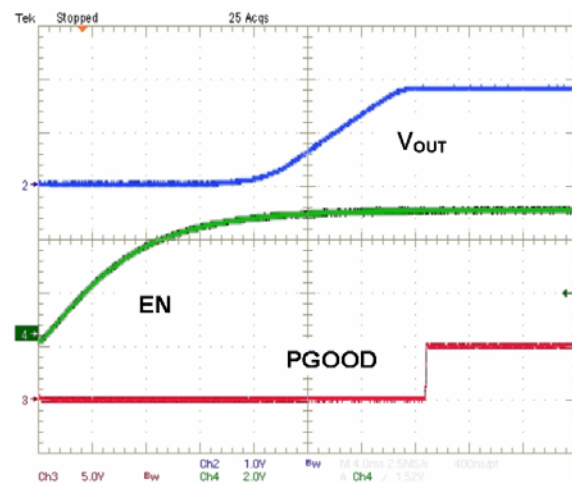


Figure 19. Start-up, 3A Load

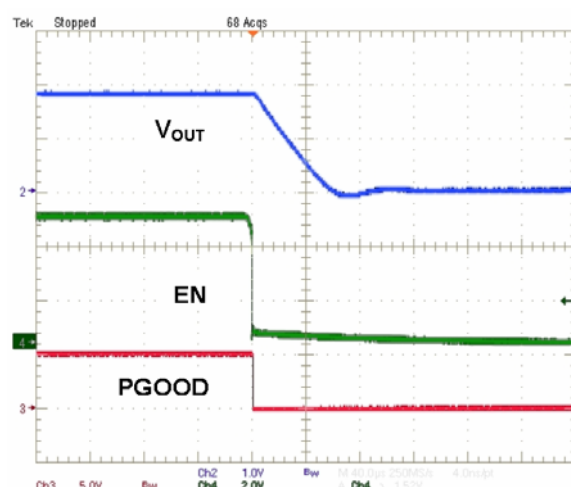


Figure 20. Shutdown, 3A Load

## Circuit Description

### Initialization

Once  $V_{CC}$  exceeds the UVLO threshold and EN is HIGH, the IC checks for an open or shorted FB pin before releasing the internal soft-start ramp (SS).

If R1 is open (as shown in Figure 1), the error amplifier output (COMP) is forced LOW and no pulses are generated. After the SS ramp times out (T1.0), an under-voltage latched fault occurs.

If the parallel combination of R1 and  $R_{BIAS}$  is  $\leq 1K\Omega$ , the internal SS ramp is not released and the regulator does not start.

### Soft-Start

Once internal SS ramp has charged to 0.8V (T0.8), the output voltage is in regulation. Until SS ramp reaches 1.0V (T1.0), the "Fault Latch" is inhibited.

To avoid skipping the soft-start cycle, it is necessary to apply  $V_{IN}$  before  $V_{CC}$  reaches its UVLO threshold.

Soft-start time is a function of oscillator frequency.

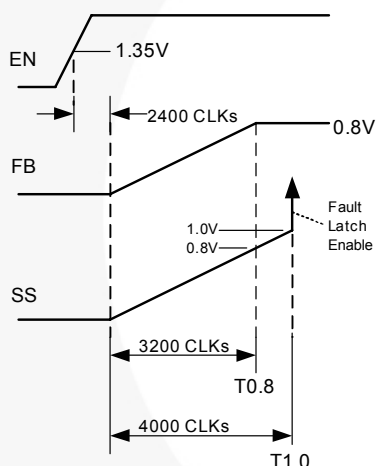


Figure 21. Soft-Start Timing Diagram

The regulator does not allow the low-side MOSFET to operate in full synchronous rectification mode until internal SS ramp reaches 95% of  $V_{REF}$  ( $\sim 0.76V$ ). This helps the regulator start against pre-biased outputs (as shown in Figure 16) and ensures that inductor current does not "ratchet" up during the soft-start cycle.

$V_{CC}$  UVLO or toggling the EN pin discharges the SS and resets the IC.

### Bias Supply

The FAN2103 requires a 5V supply rail to bias the IC and provide gate-drive energy and controller power. Connect a  $\geq 1.0\mu f$  X5R or X7R decoupling capacitor between  $V_{CC}$  and PGND. Whenever the EN pin is pulled up to  $V_{CC}$ , the 5V supply connected to  $V_{CC}$  should be turned ON after  $V_{IN}$  comes up. If the power supply is turned ON using EN pin with an external control after  $V_{CC}$  and  $V_{IN}$  come up, the  $V_{CC}$  and  $V_{IN}$  power sequencing is not relevant.

Since  $V_{CC}$  is used to drive the internal MOSFET gates, supply current is frequency and voltage dependent. Approximate  $V_{CC}$  current ( $I_{CC}$ ) can be calculated using:

$$I_{CC}(mA) = 4.58 + \left[ \left( \frac{V_{CC} - 5}{227} + 0.013 \right) \cdot (f - 128) \right] \quad (1)$$

where frequency (f) is expressed in KHz.

### Setting the Output Voltage

The output voltage of the regulator can be set from 0.8V to  $\sim 80\%$  of  $V_{IN}$  by an external resistor divider (R1 and  $R_{BIAS}$  in Figure 1).

The internal reference is 0.8V with 650nA, sourced from the FB pin to ensure that if the pin is open, the regulator does not start.

The external resistor divider is calculated using:

$$\frac{0.8V}{R_{BIAS}} = \frac{V_{OUT} - 0.8V}{R1} + 650nA \quad (2)$$

Connect  $R_{BIAS}$  between FB and AGND.

### Setting the Frequency

Oscillator frequency is determined by an external resistor,  $R_T$ , connected between the R(T) pin and AGND:

$$f_{(KHz)} = \frac{10^6}{(65 \cdot R_T) + 135} \quad (3)$$

where  $R_T$  is expressed in  $K\Omega$ .

$$R_{T(K\Omega)} = \frac{(10^6 / f) - 135}{65} \quad (4)$$

where frequency (f) is expressed in KHz.

The regulator does not start if  $R_T$  is left open.

## Calculating the Inductor Value

Typically the inductor is set for a ripple current ( $\Delta I_L$ ) of 10% to 35% of the maximum DC load. Regulators requiring fast transient response use a value on the high side of this range, while regulators that require very low output ripple and/or use high-ESR capacitors restrict allowable ripple current:

$$\Delta I_L = \frac{V_{OUT} \cdot (1 - D)}{L \cdot f} \quad (5)$$

where  $f$  is the oscillator frequency and:

$$L = \frac{V_{OUT} \cdot (1 - D)}{\Delta I_L \cdot f} \quad (6)$$

## Setting the Ramp Resistor Value

The internal ramp voltage excursion ( $\Delta V_{RAMP}$ ) during  $t_{ON}$  should be set to 0.6V.  $R_{RAMP}$  is approximately:

$$R_{RAMP}(K\Omega) = \frac{(V_{IN} - 1.8) \cdot V_{OUT}}{18 \times 10^{-6} \cdot V_{IN} \cdot f} - 2 \quad (7)$$

where frequency ( $f$ ) is expressed in KHz.

## Setting the Current Limit

There are two levels of current-limit thresholds in FAN2103. The first level of protection is through an internal default limit set at the factory to limit output current beyond normal usage levels. The second level of protection is a flexible one to be set externally by the user. Current-limit protection is enabled whenever the lower of the two thresholds is reached. The FAN2103 uses its internal low-side MOSFET for current-sensing. The current-limit threshold voltage ( $V_{ILIM}$ ) is compared to the voltage drop across the low-side MOSFET, sampled at the end of each PWM off-time/cycle. The internal default threshold (with  $I_{LIM}$  open) is temperature compensated.

The 10 $\mu$ A current sourced from the ILIM pin can be used to establish a lower, temperature-dependent, current-limit threshold by connecting an external resistor ( $R_{ILIM}$ ) to AGND:

$$R_{ILIM}(K\Omega) = 10.4 \cdot K_T \cdot (I_{OUT} - \frac{\Delta I_L}{2}) + 142.5 \quad (8)$$

where:

$I_{OUT}$  = desired current limit set point in Amps,  
 $K_T$  = the normalized temperature coefficient of the low-side MOSFET (Q2) from Figure 8.

After 16 consecutive, pulse-by-pulse, current-limit cycles, the fault latch is set and the regulator shuts down. Cycling  $V_{CC}$  or EN restores operation after a normal soft-start cycle (refer to *Auto-Restart* section).

The over-current protection fault latch is active during the soft-start cycle. Use a 1% resistor for  $R_{ILIM}$ .

## Loop Compensation

The loop is compensated using a feedback network around the error amplifier. Figure 22 shows a complete Type-3 compensation network. Type-2 compensation eliminates  $R_3$  and  $C_3$ .

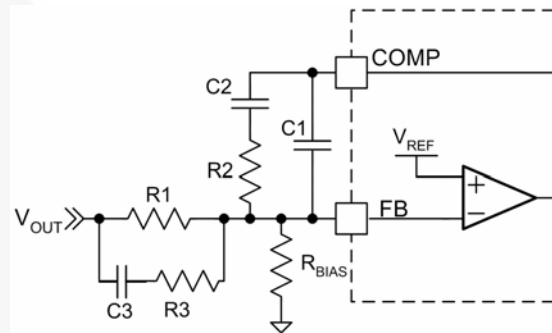


Figure 22. Compensation Network

Because the FAN2103 employs summing current-mode architecture, Type-2 compensation can be used for many applications. For applications that require wide loop bandwidth and/or use very low-ESR output capacitors, Type-3 compensation may be required.

$R_{RAMP}$  provides feedforward compensation for changes in  $V_{IN}$ . With a fixed  $R_{RAMP}$  value, the modulator gain increases as  $V_{IN}$  is reduced, which could make it difficult to compensate the loop. For designs with low input voltages (3V to 6.5V), it is recommended that a separate  $R_{RAMP}$  and the compensation component values are used as compared to designs with  $V_{IN}$  between 6.5V and 24V.

## Protection

The converter output is monitored and protected against extreme overload, short-circuit, over-voltage, and under-voltage conditions.

An internal "Fault Latch" is set for any fault intended to shut down the IC. When the fault latch is set, the IC discharges  $V_{OUT}$  by enhancing the low-side MOSFET until  $FB < 0.25V$ . The MOSFET is not turned on again unless  $FB > 0.5V$ . This behavior discharges the output without causing undershoot (negative output voltage).

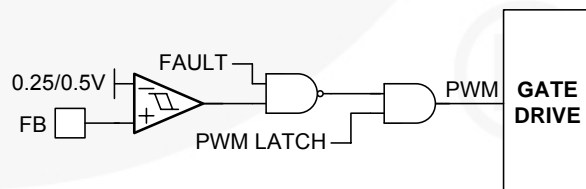


Figure 23. Latched Fault Response

## Under-Voltage Shutdown

If FB remains below the under-voltage threshold for 16 consecutive clock cycles, the fault latch is set and the converter shuts down. This fault is prevented from setting the fault latch during soft-start.

## Over-Voltage Protection / Shutdown

If FB exceeds  $115\% \cdot V_{REF}$  for two consecutive clock cycles, the fault latch is set and shutdown occurs.

A shorted high-side MOSFET condition is detected when SW voltage exceeds  $\sim 0.7V$  while the low-side MOSFET is fully enhanced. The fault latch is set immediately upon detection.

The two fault protection circuits above are active all the time, including during soft-start.

## Auto-Restart

After a fault, EN is discharged with  $1\mu A$  to a  $1.1V$  threshold before the  $800K\Omega$  pull-up is restored. A new soft-start cycle begins when EN charges above  $1.35V$ .

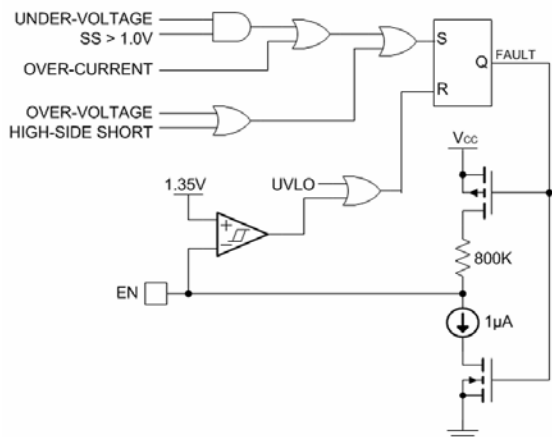
Depending on the external circuit, the FAN2103 can be provisioned to remain latched-off or automatically restart after a fault.

**Table 1. Fault / Restart Provisioning**

EN pin	Controller / Restart State
Pull to GND	OFF (disabled)
V <sub>CC</sub>	No restart – latched OFF (after V <sub>CC</sub> comes up)
Open	Immediate restart after fault
Cap to GND	New soft-start cycle after: $t_{DELAY} (ms) = 3.9 \cdot C(nf)$

With EN left open, restart is immediate.

If auto-restart is not desired, tie the EN pin to the V<sub>CC</sub> pin or pull it high after V<sub>CC</sub> comes up with a logic gate to keep the  $1\mu A$  current sink from discharging EN to  $1.1V$ .



**Figure 24. Fault Latch with Delayed Auto-Restart**

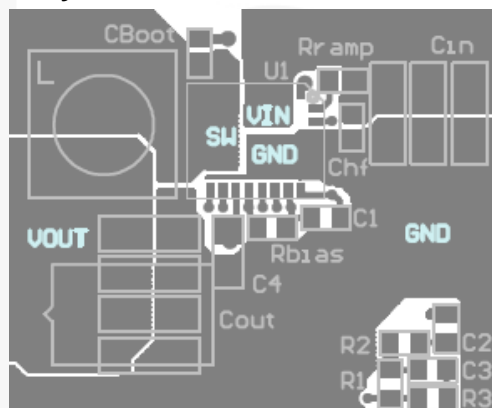
## Over-Temperature Protection

FAN2103 incorporates an over-temperature protection circuit that sets the fault latch when a die temperature of about  $160^{\circ}C$  is reached. The IC is allowed to restart when the die temperature falls below  $130^{\circ}C$ .

## Power Good (PGOOD) Signal

PGOOD is an open-drain output that asserts LOW when V<sub>OUT</sub> is out of regulation, as measured at the FB pin (thresholds are specified in the Electrical Specifications section). PGOOD does not assert HIGH until the fault latch is enabled (T1.0).

## PCB Layout



**Figure 25. Recommended PCB Layout**

## Physical Dimensions

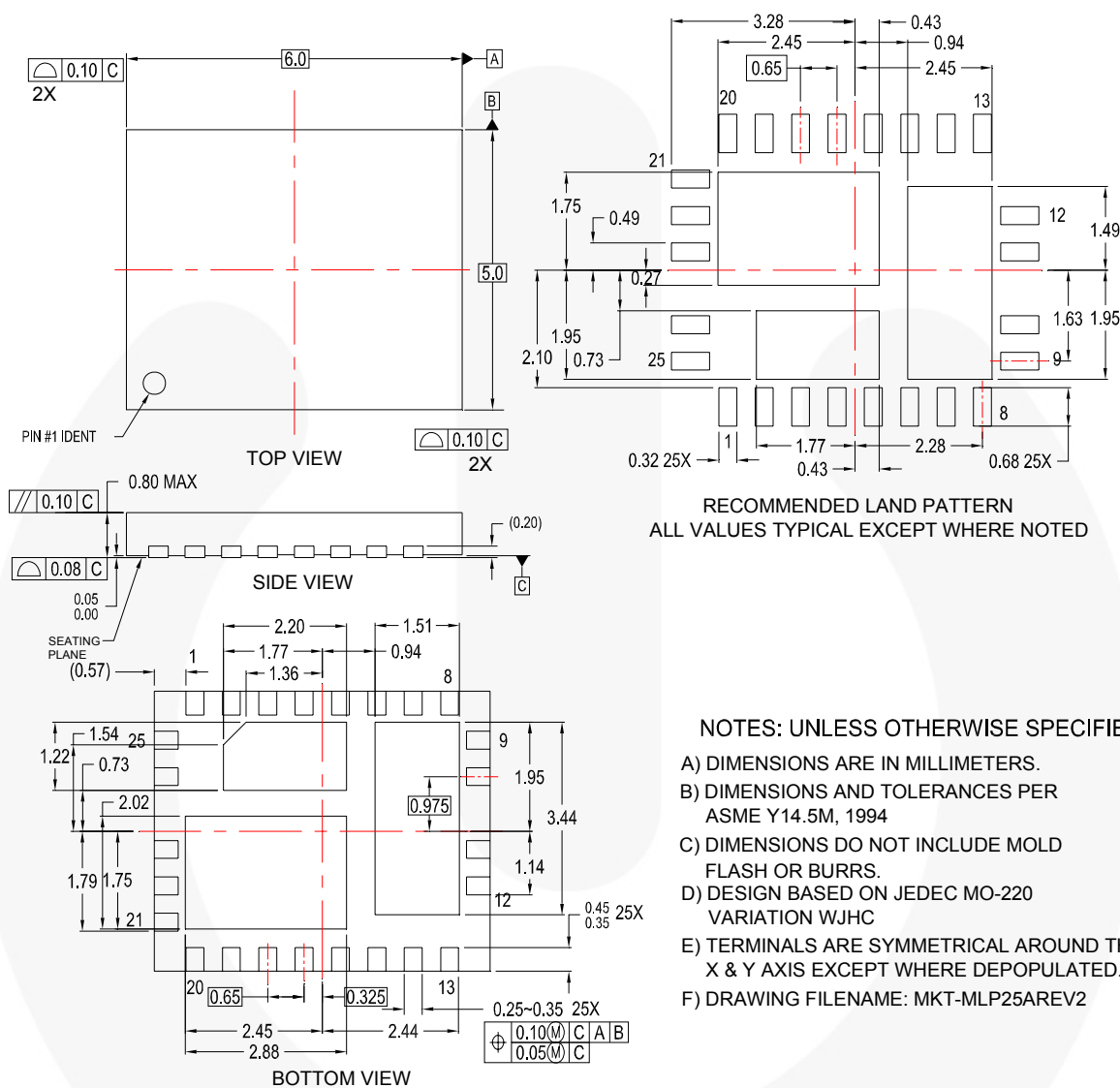


Figure 26. 5x6mm Molded Leadless Package (MLP)

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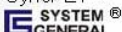


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